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Seasonality, depth and habitat distribution of breeding males of *Oreochromis* spp., ' chambo ', in Lake Malawi National Park

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The temporal pattern of breeding by chambo, *Oreochromis* spp., and the vertical and horizontal distribution of territorial males at the Golden Sands-Chembe beach were examined in the Cape Maclear region of Lake Malawi National Park. The breeding season began in September and ended in April, and the number of breeding males between 3 and 15 m was approximately 25 ha^{-1}. Along the beach studied, the highest concentrations of nests were found at the ends of the beach near rocks, and the lowest number of breeding males occurred in front of Chembe village

Results from experimental gill netting demonstrated that the catches of chambo within the 100-m Lake Malawi National Park ' no fishing zone ' were identical to those outside the 100-m zone, suggesting that fishermen would suffer little or no loss in catch by being encouraged to fish more than 100 m from the shore. Such a reduction in fishing and disturbance of the shallow water breeding grounds would probably enhance the chambo fishery. Preliminary data are provided on the chambo nest forms found in the Cape Maclear region, and further research is suggested to resolve the question of how many species comprise the genus *Oreochromis* in Lake Malawi.

I. INTRODUCTION

The ' tilapia ' fishery has long been recognized as one of the most important commercial fisheries in Lake Malawi. Ricardo Bertram *et al.* (1942) discovered that this fishery was on several closely related species. Trewavas (1941) described two species, bringing the total of known species of tilapiine fishes from Lake Malawi to five. She further indicated that another species might exist which could be distinguished by the breeding colour of the male. Lowe (1952, 1953) distinguished between two ecotypes of *Oreochromis squampinnis* (Gunther) and described the black breeding form of the male as *Oreochromis saka* (Lowe), and reserved *O. squamipinnis* for the species with the blue breeding male. Collectively, these two species along with *Oreochromis lidole* (Trewavas) and *Oreochromis karongae* (Trewavas) are known commonly as 'chambo'. The species overlap in their meristic counts, but *O. squamipinnis* can be separated by the blue breeding colour of the male (Trewavas, 1983). Lowe (1953) concluded that male colour differences could be the important characteristic in female choice and might play a role in the speciation process. Later Malawi studies have also confirmed that colouration is important in distinguishing many species (Holzberg, 1978; Marsh *et al.*, 1981; McKaye & Stauffer, 1986; Ribbink *et al.*, 1983; Schroder, 1980), and this general conclusion has been confirmed by genetic analysis (McKaye *et al.*, 1982, 1984).

Chambo are mouthbrooders, like the other endemic cichlids of Lake Malawi (McKaye, 1984). The male defends a nest which functions as a display site for

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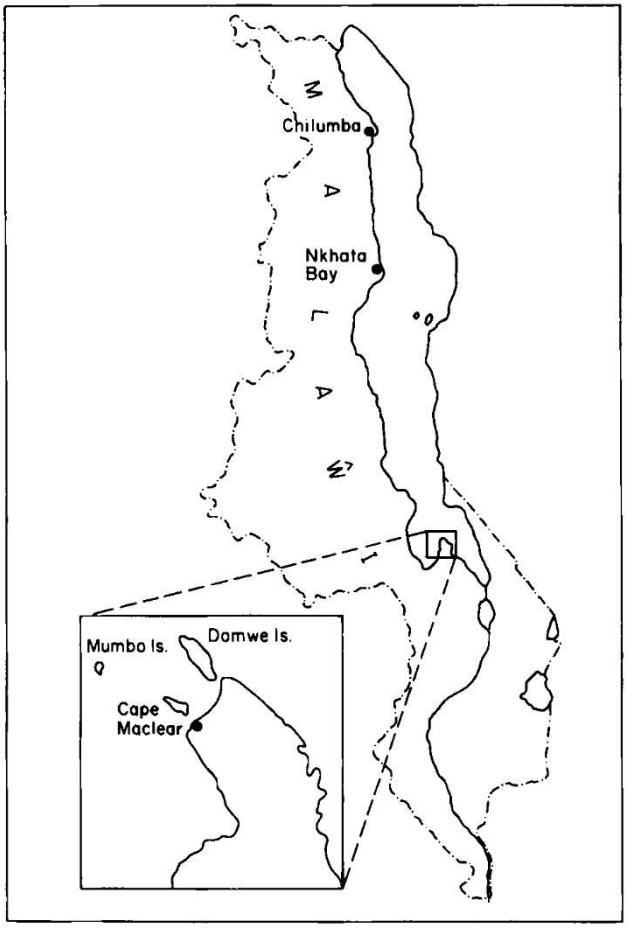

FIG. 1. Lake Malawi and the location of the Cape Maclear research station in Lake Malawi National Park.

attracting females. Once the eggs are laid, taken into the mouth and fertilized, the females leave the breeding areas to move primarily into the reeds (Lowe, 1952). All parental care is maternal. Earlier studies reported that the southern-dwelling species *O. squamipinnis*, *O. saka*, and *O. lidole* reproduce at different times of the year: *O. squamipinnis* during December–April; *O. saka*, August–November; *O. lidole*, October–November (Lowe, 1952). Also, differences in depth of breeding were reported: *O. lidole* at 16 m; *O. squamipinnis*, 8 m; *O. saka*, *c.* 4 m (Trewavas, 1983).

Chambo are important food fishes for the people living in the Cape Maclear region of Lake Malawi National Park (Fig. 1). They are also an important tourist attraction for visitors to the park, as they provide a spectacular display of courtship and nest building behaviour when the males are left undisturbed. Clearly, management of the fishes, particularly chambo occurring within the park, is important for food, education and tourism. Carter *et al.* (1984), therefore, proposed that no fishing be allowed within 100 m off Chembe-Golden Sands beach or Otter Point (Fig. 2).

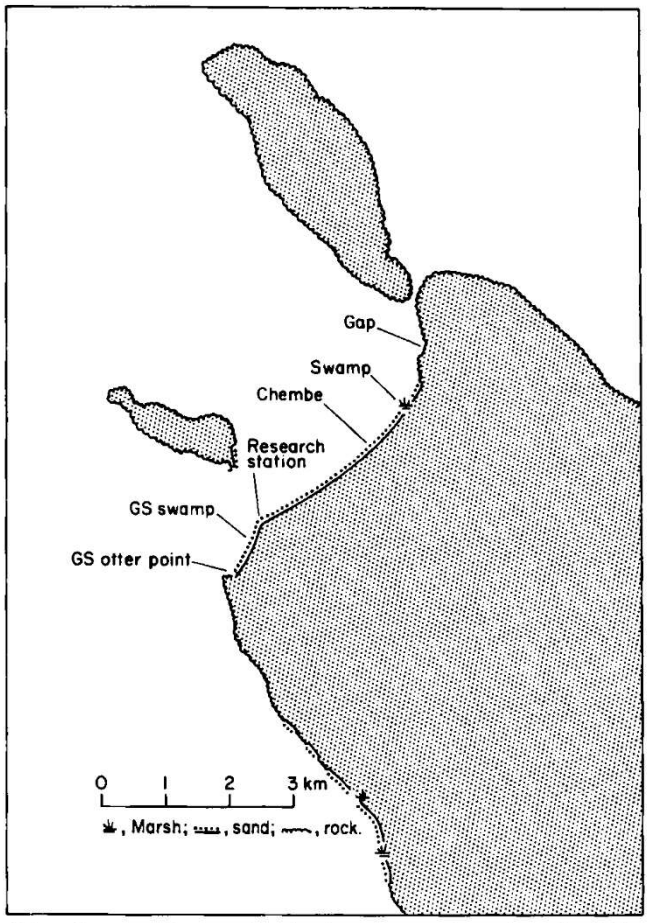

FIG. 2. Location of the primary study area with the six transect regions along the Golden Sands-Chembe Beach in Lake Malawi National Park.

We initiated the present study to determine (1) the breeding seasonality of chambo in the Cape Maclear region, (2) their shallow water (< 15 m) breeding depths, and (3) the relative abundance of chambo nests along the Chembe-Golden Sands beach. Furthermore, fish were sampled to determine what the relative gill net catches would be within the 100-m restricted zone as compared with in deeper water, with a view to deciding whether fishermen could harvest chambo without disturbing the shallow-water nesting males.

At the beginning of this study we thought that the three closely related species, *O. squamipinnis*, *O. saka* and *O. lidole*, could be distinguished on the basis of (1) colour of the breeding male, (2) breeding seasonality, and (3) depth at which they breed, but we were unable to do so consistently: the overlap in the important distinguishing behavioural characteristics was greater than had been expected from the literature. The males changed colour *in situ* from black to blue and back again on several occasions and could not be assigned with confidence to any species on the basis of underwater observations (for description of similar colour changes from aquaria studies see Berns *et al.*, 1978). Although such colour changes might

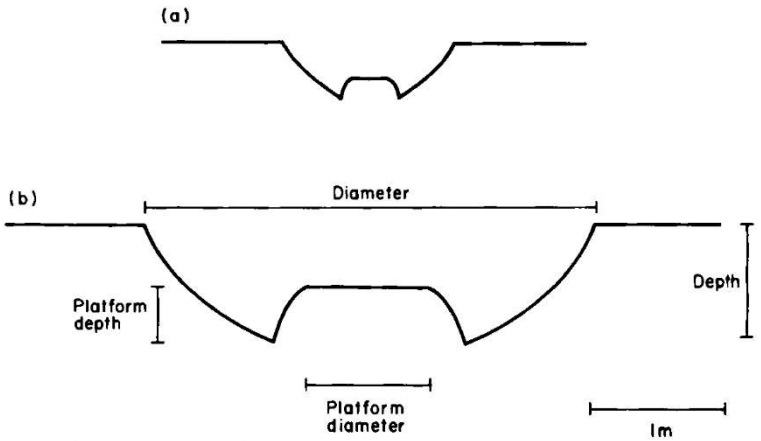

FIG. 3. Two primary nest forms of *Oreochromis* spp. in Lake Malawi National Park.

be a characteristic of *O. squamipinnis*, we did not feel confident in distinguishing species solely on the basis of underwater observations. Therefore, the data are combined into the single category *Orechromis* spp., henceforth referred to collectively as chambo.

II. METHODS

BREEDING SEASONALITY AND SHALLOW WATER DEPTH DISTRIBUTION OF CHAMBO NESTS

Counts of chambo nests were made bi-weekly at six different sites spaced along the 4-km beach at Cape Maclear (Fig. 2) from August 1981 to November 1982 and again from December 1983 to April 1984. At each site, ten 400-m^2 transects at ten depths between 0 and 15 m were made. General observations of the distribution of deeper nests and their measurements were made in March 1987.

NEST MEASUREMENTS

Eight measurements of each nest were made (Fig. 3): diameter, depth, platform diameter and platform depth in one plane, then the same features at right angles to the original ones.

GILL NET COMPARISONS

Two sets of gill nets (89 mm mesh × 4-ply undyed twine) 100 m long and 40 meshes deep, purchased locally in Malawi, were used. Both were set every night and alternated between depths to elminate any possibility of a ' net effect '. One net was set within 100 m of shore at a depth of 5–30 m, and the other approximately 100 m from shore in a depth of approximately 60 m. The four netting lcoations were (1) in front of the research station, (2) within 500 m of the station, (3) at the GS Otter Point site, and (4) at Chembe. The state of the moon was recorded as to whether or not it was within 3 days of being full (i.e., light throughout the night), new moon (no light the entire night), first quarter, or last quarter. A total of 108 settings were made from March to October 1984.

A two-way factorial ANOVA, followed by a Duncan's multiple range test, was used to determine the effects of depth (shallow, deep) and moon phase (new moon, first quarter, last quarter, full moon) on the number of chambo captured.

III. RESULTS

BREEDING SEASONALITY AND DISTRIBUTION OF NESTS

The chambo breeding season in the Cape Maclear region begins in September and ends in April, with the breeding peak between December and March (Fig. 4).

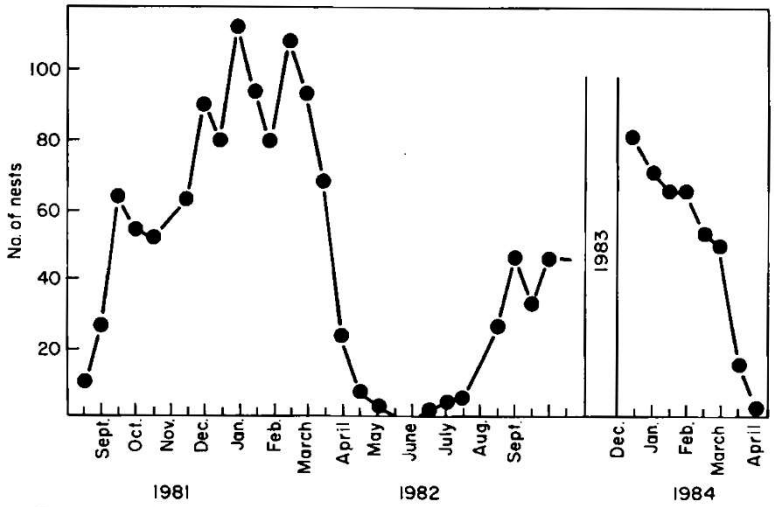

FIG. 4. Breeding seasonality of *Oreochromis* spp. (no transects were made from November 1982 to November 1983).

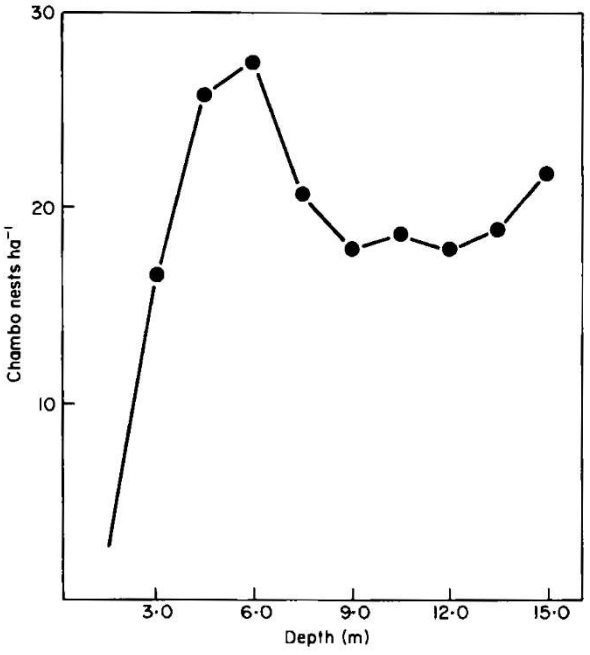

FIG. 5. Depth distribution of *Oreochromis* spp. nest between 0 and 15 m.

Between 3·0 and 15·0 m, the number of nesting males averaged approximately 25 ha^{-1} (Fig. 5). Along the Golden Sands-Chembe beach the highest concentration of nests occurred at the ends of the beach near the rocks at both Golden Sands and the Gap. The fewest nests were in front of Chembe Village (Fig. 6).

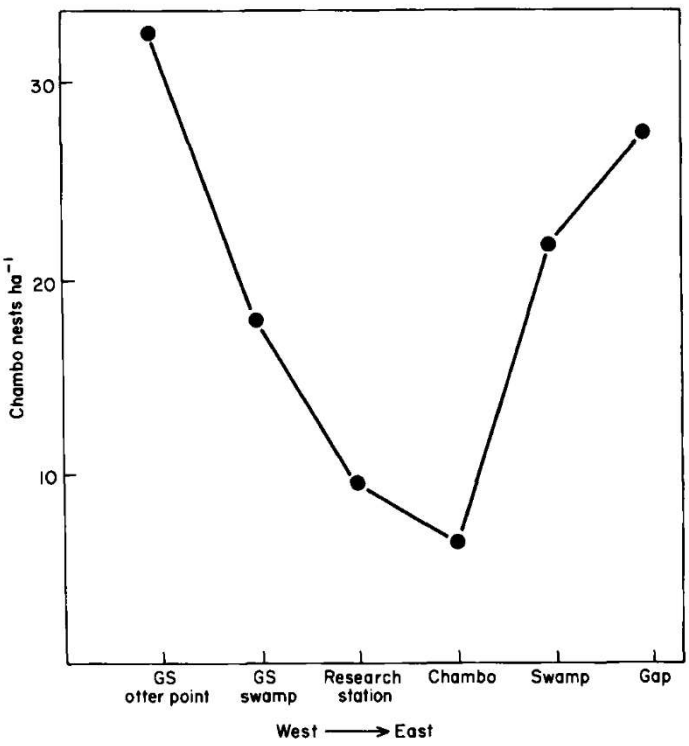

FIG. 6. Distribution of *Oreochromis* spp. nests along the Golden Sands-Chembe beach of Lake Malawi National Park.

TABLE I. Mean dimensions (cm) and standard deviations (in parentheses) of chambo nests

Nest type	*n*	Diameter	Depth	Platform diameter	Platform depth
A	20	110·8 (26·9)	35·1 (12·7)	35·6 (7·4)	3·6 (1·7)
B	10	300·7 (45·2)	64·5 (9·9)	36·6 (8·9)	30·5 (9·1)

NEST MEASUREMENTS

Chambo nests were characterized by a crater in the sand within which an elevated platform was built up (Fig. 3). Two forms of the nest were found in the Cape Maclear region: the most commmon form [Fig. 3(a)] had an average diameter of slightly over 1 m; the less common and deeper-water form was larger, with the diameter almost three times larger and the crater twice as deep as the smaller form [Fig. 3(b), Table I].

TABLE II. Analysis of variance of the effects of depth (deep and shallow) and moon phase (new moon, first quarter, last quarter, full moon) on the number of chambo captured

Source	d.f.	Sum of squares	Mean square	*F*-value	Significance
Depth	1	0·75	0·75	0·12	
Moon phase	3	142·8	47·6	7·63	*
Depth moon phase	3	10·85	3·6	0·58	
Error	100	623·9			

* = $P < 0{\cdot}05$.

TABLE III. Duncan's multiple range test of the effect of moon phase on the number of chambo collected. Means with the same letter are not significantly different ($P > 0{\cdot}05$)

Duncan grouping	Mean	*n*	Moon phase
a	3·5	28	New moon
ab	2·7	30	First quarter
bc	1·6	16	Last quarter
c	0·6	34	Full moon

GILL NET COMPARISONS

The two-way ANOVA indicated that there was no significant effect ($P > 0{\cdot}05$) between the number of chambo caught at different depths or of the interaction between depth and moon phase on the number of chambo caught (Table II). However, there was a significant effect of moon phase on the number of chambo captured (Table II). Duncan's multiple range test (Table III) showed that the number of chambo captured during the new moon phase (mean = 3·5) was significantly different ($P < 0{\cdot}05$) from the number caught in the full moon phase (mean = 0·6). Both deep and shallow nets averaged approximately 1500 g of fish per setting. There were no differences by depth in the weights of the individuals. The average sized chambo caught weighed approximately 300 g, and the greatest number caught in any net was twelve. The total catch by weight during the full moon was half that caught during other periods of the lunar cycle.

IV. DISCUSSION

The present study corroborates the earlier reports that members of the genus *Oreochromis* breed between August and April (Lowe, 1952; Trewavas, 1983). The major reproductive activity in the Cape Maclear area was between December and March, after which time the number of breeding males declined considerably. Throughout this entire period, black males were seen breeding from 2 m down to

our deepest diving depths at 40 m. Whether or not these were males of three or more different species, i.e., *O. saka*, *O. lidole* or the black form of *O. squamipinnis*, was not determined in this study. The systematic confusion was further complicated by the fact that blue males (*O. squamipinnis*?) were also seen on smaller nests [Fig. 3(a)].

The larger nests [Fig. 3(b)] were never observed with a male guarding them. However, these nests were clearly occupied and not silted as occurs when a nest becomes abandoned. We also disturbed the nests by either placing objects in the centre or stirring the sand in the nest. When we returned the following day the disturbed nest had always been modified to its original form. The larger nests were usually found below 10 m depth and were much rarer than the shallow nests. The depth at which we found these nests is consistent with that reported for *O. lidole* by Lowe (1952).

The number of chambo nests appeared to be constant between 3 and 15 m depths. However, within the Cape Maclear region the distribution of chambo males was not uniform along the Chembe beach, the highest density being at either end of the beach at Golden Sands-Otter Point and the Gap at Domwe Island, and the lowest in the centre of the beach (Figs 2, 6).

Our fishing data corroborated the transect data, as equal numbers of chambo were caught in nets set in shallow (less than 100 m from the shore) and deep water. These data strongly suggest that the chambo stock 100 m offshore includes the shallow-water chambo. Hence, the fishermen, if provided with longer pull lines to set their nets, would suffer little or no loss in catch by being prevented from fishing within 100 m of the shore. Such a reduction in fishing and disturbance of the shallow water breeding grounds would probably enhance the chambo fishery; a partial respite for breeding fish might be provided. Future tagging studies could determine whether this hypothesis is correct. If it is, the present regulation will aid in the recruitment to the stock as a whole. Furthermore, opportunities for tourists to observe the reproductive behaviour of these magnificent fish would be enhanced in shallow water.

The only variable which significantly affected the catch of chambo during the course of our study was the phase of the moon. The fish appear to move at night, and at reduced light levels are more likely to swim into a net. This was dramatically demonstrated by the large increase in chambo caught during the period of the new moon when compared to the full moon.

Observing the reproductive behaviour of chambo was exceedingly difficult, as the fish usually fled in the presence of a diver. For this reason, given the scope of the study, no decisions concerning the number of species present were made. Hopefully, with the introduction of underwater video systems, the relevant behavioural observations will be possible.

We are puzzled by some of the anomalies in our data and the discrepancies with the data reported by Trewavas and Lowe discussed above. On the basis of nest form, there are clearly a minimum of two species in the Cape Maclear region. However, more than the three southern species already described by the earlier workers might possibly exist and are confounding our results. Conceivably, there is a species that changes from black to blue and back to black again (see Trewavas, 1983); alternatively, the fish exhibiting these colour changes is *O. squamipinnis* which can at times be primarily black with only a small amount of blue on the head

(Berns *et al.*, 1978; R. H. Lowe, pers. comm.). A detailed analysis of the genetics, reproductive behaviour and morphometric analysis of fish caught on nests and at different depths is required to resolve this intriguing systematic question. Such a study is particularly crucial for the management of the chambo and determination of the stocks in both L. Malawi and L. Malombe.

We conclude that the present fishing regulations in Lake Malawi National Park aid in conserving the chambo, while also allowing both scientists and tourists an opportunity to observe these fish in an undisturbed state. Hopefully, the data from this report will encourage further examination of the reproductive biology of these fishes and be helpful in the fisheries extension programme to explain to the local fishermen the advantages of fishing 100 m from the beach, and not during peak reproductive periods.

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